



IEPR Presentation: Inter-Model Comparison of California Energy and Climate Policy Models

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California Energy Commission

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Overview

- Acknowledgments
- A few words about models, scenarios and forecasts
- Model comparison overview and findings
- Observations and key takeaways
- Questions

Acknowledgements

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A few words about models

"Essentially, all models are wrong…

…but some are useful"

Professor George Box, University of Wisconsin

A few words about scenarios

"Scenarios are stories that consider "what if?" questions. Whereas forecasts focus on probabilities, scenarios consider a range of plausible futures and how these could emerge from the realities of today. They recognize that people hold beliefs and make choices that lead to outcomes."

Ref: Shell, http://www.shell.com/global/future-energy/scenarios.html

And ‘forecasting’…

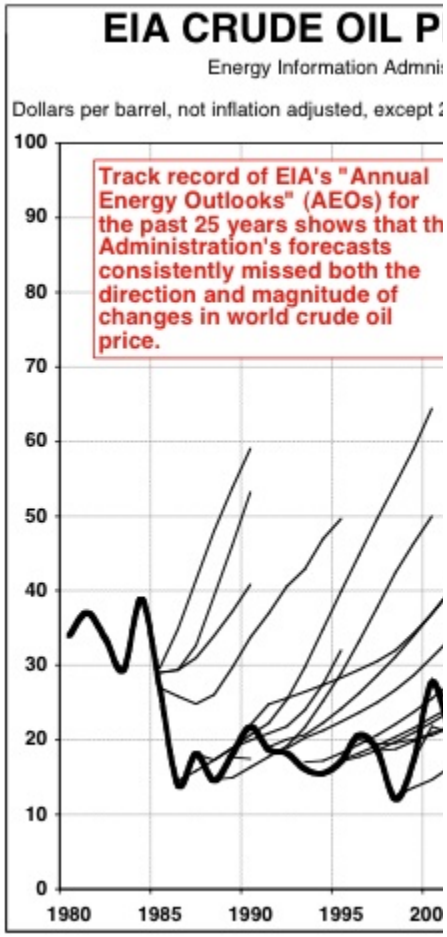
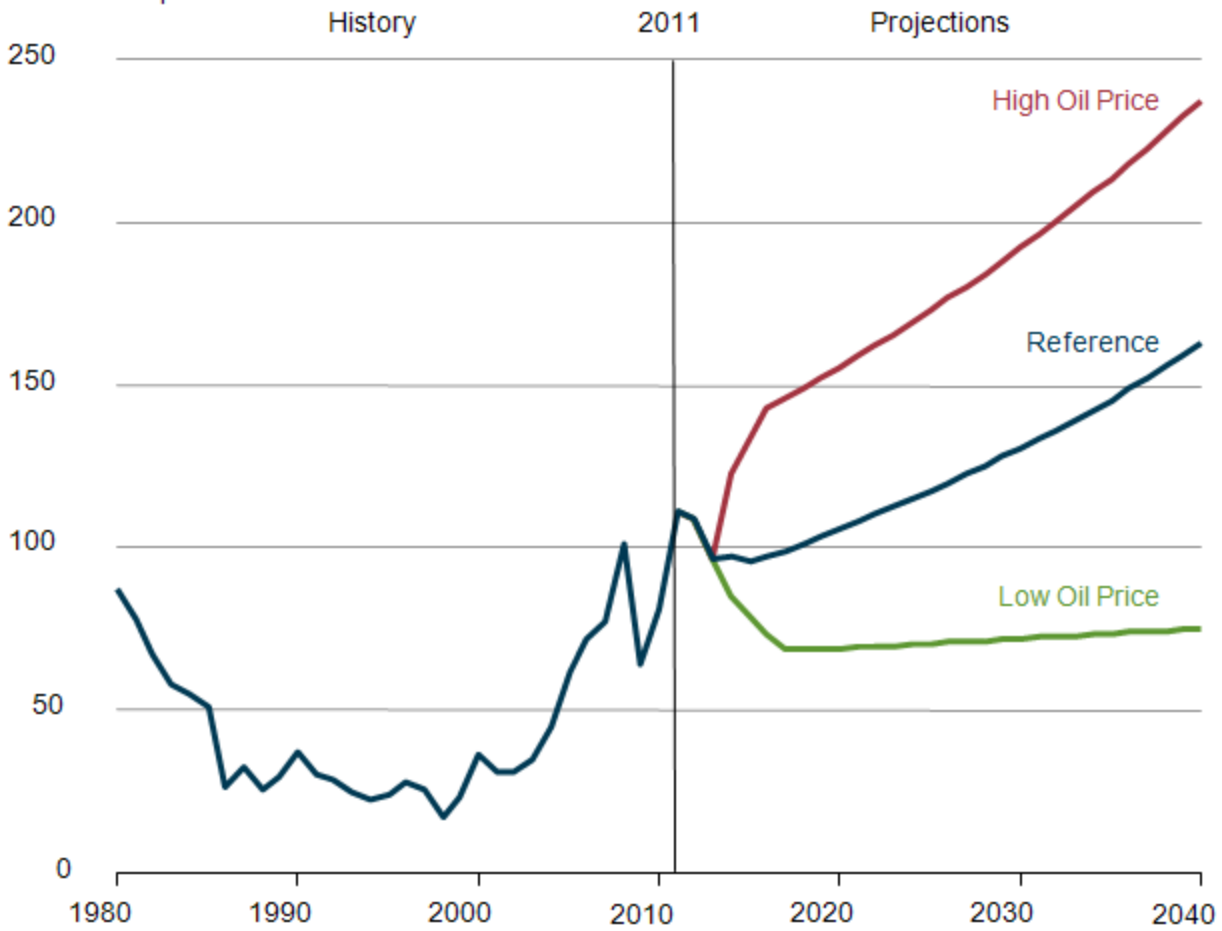


Figure 5. Average annual Brent spot crude oil prices in three cases, 1980-2040

2011 dollars per barrel



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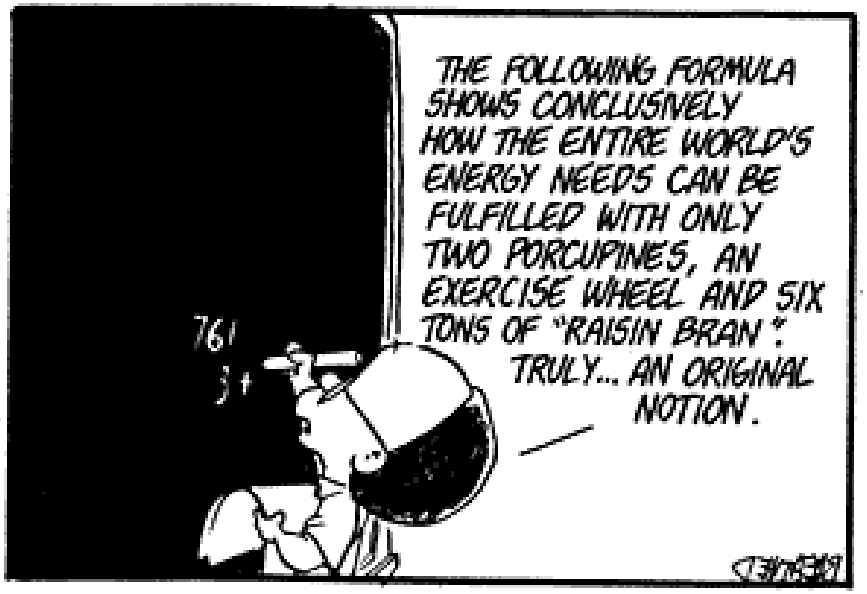
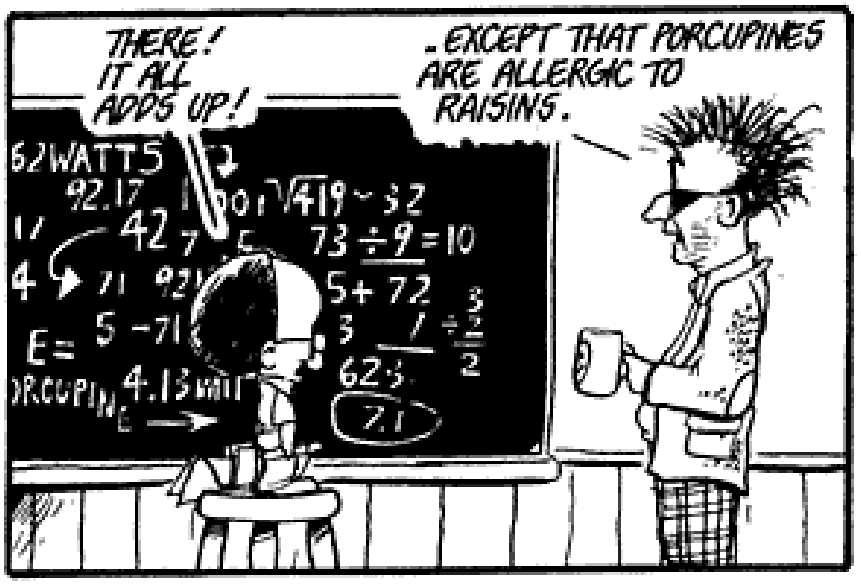
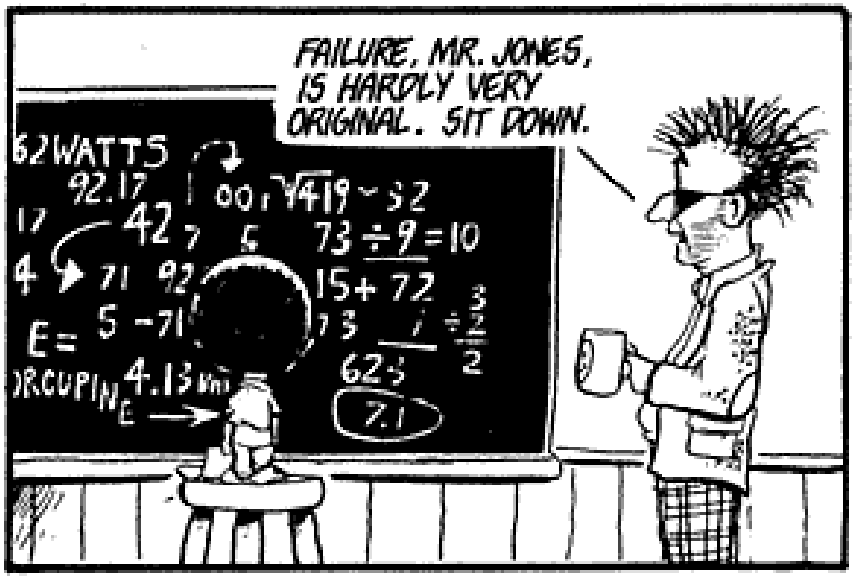
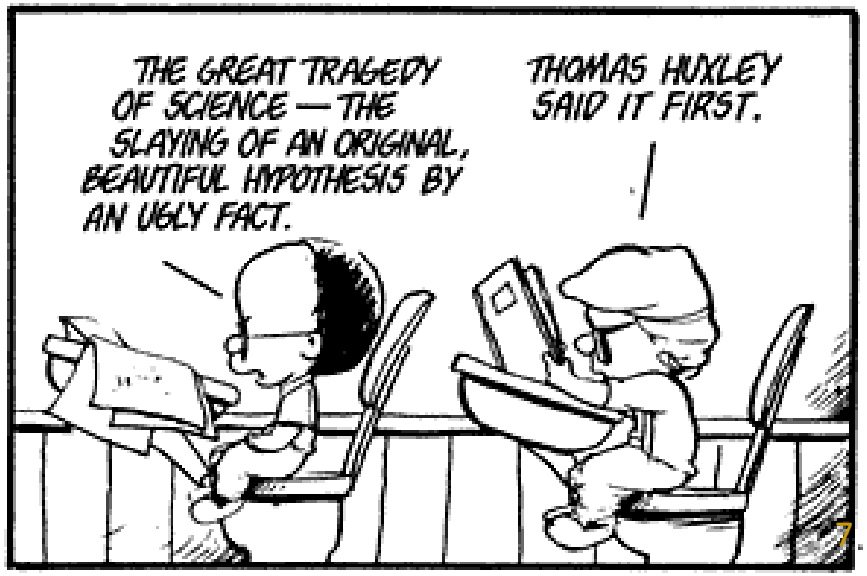
Except that porcupines are allergic to raisins…

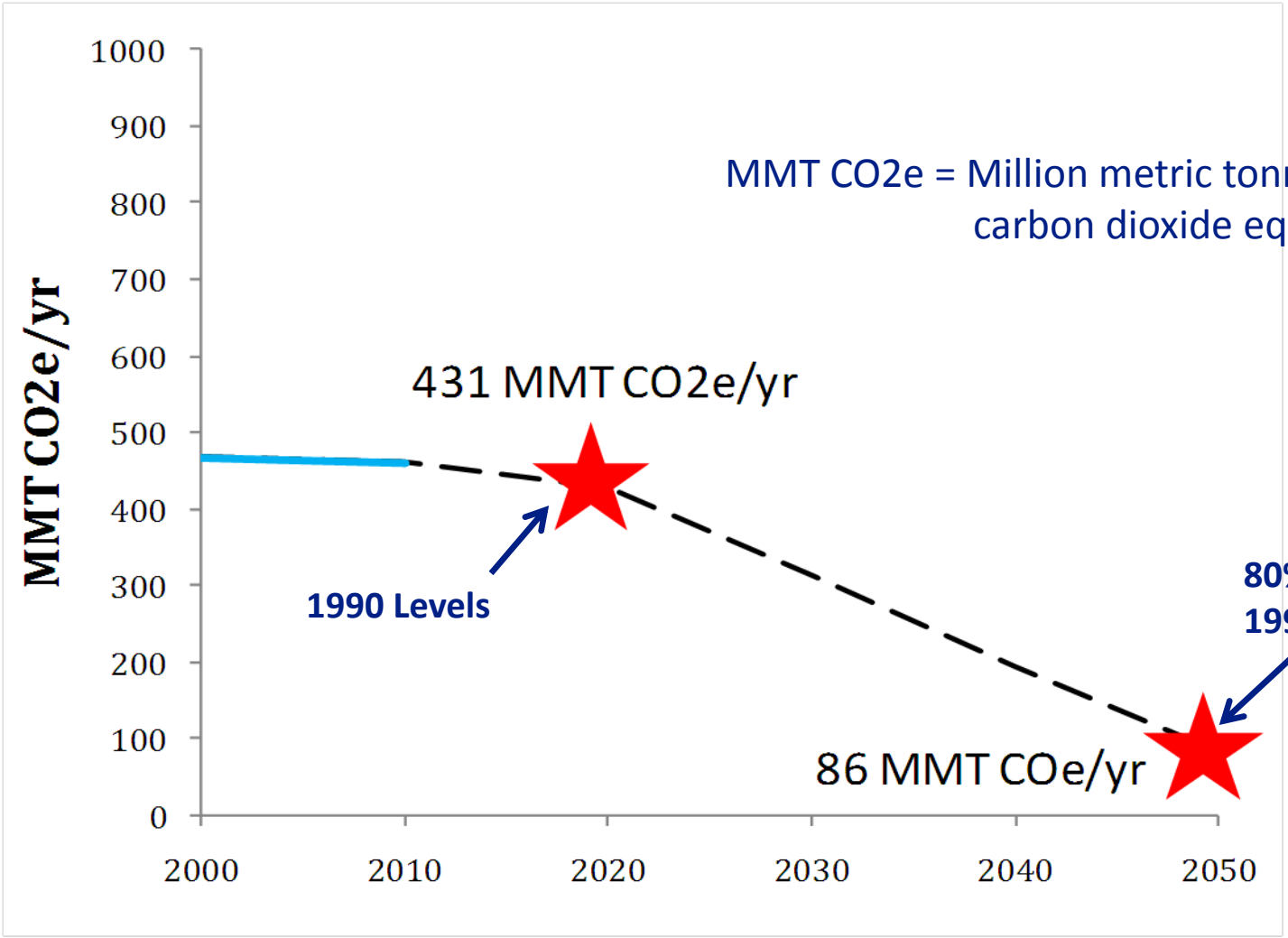








California's Goals:
Reach 1990 levels by 2020 and 80% reduction by 2050



Need for Mid-term GHG Target

- Update to AB 32 Scoping Plan (2014):

  "**A mid-term statewide emission limit** will ensure that the State stays on course to meet our long-term goal and continues the success it has achieved thus far in reducing emissions." (CARB, 2014, p. 39)

- Governor's Environmental Goals and Policy Report (2013):

  "…**the state needs a mid-term emission reduction target** to provide a goalpost to guide near-term investment and policy development. A mid-term target will allow us to gauge current actions relative to our climate goals and serve to provide a clear sign of the state's commitment to achieving long-term climate stabilization. This commitment will send a strong signal of support for the innovators and entrepreneurs to drive technology and development to tackle the challenge of climate change." (OPR, 2014, p. 6)

Model Questions

- How might California's energy system evolve to 2030 & 2050:
  - Greenhouse Gas (GHG) trajectories?
  - Fuel mix and technology mix?
  - Infrastructure build rate?
  - Air quality?

- What assumptions drive these results?

- What are common insights across models? Where do they diverge?

CA Energy Models/Reports Reviewed

Model	Group (lead)
ARB VISION	California Air Resources Board (CARB)
BEAR	UC Berkeley (Roland-Holst)
CA-TIMES	UC Davis (Yang, Yeh)
CCST View to 2050	CCST (Long)
CCST (Bioenergy)	CCST (Youngs)
E-DRAM	UCB/CARB (Berck)
Energy 2020	ICF/CRA
GHGIS	LBNL (Greenblatt)
IEPR 2013/CED 2013	California Energy Commission (CEC)
LEAP-SWITCH	UC Berkeley/LBNL (Nelson, Wei)
MRN-NEEM	EPRI/CARB
PATHWAYS	E3/LBNL (Williams)
Wind Water Solar (WWS)	Stanford/UCD (Jacobson, Delucchi)

Qualitative Comparison

	ARB-VISION	BEAR	CA-TIMES	GHGIS	LEAP-SWITCH	PATHWAYS
Development						
Modeling team(s)	CARB	UC Berkeley	UC Davis	LBL/ARB	LBL, UCB	E3/LBL
Software	Excel	GAMS	GAMS	Excel	AMPL	Excel
Structure						
Sectors modeled	Transportation	All	All	All	All	All
Solution algorithm	Fleet turnover / spreadsheet	General Equilibrium	Optimization or Partial Equilibrium	Scenario-based	Spreadsheet (LEAP) + Optim. (SWITCH)	Backcasting
Forecast period	2000-2050	2005-2080	2010-2055	2010-2050	2010-2050	2008-2050
Features						
Endogenous tech learning						
Spatial disaggregation in CA						
Vehicle stock turnover						
Power plant stock turnover						
Models criteria pollutants						
Uses electricity dispatch model						
Interactions with out-of-state						
Perfect foresight to 2050?						
Economics						
Measures economic welfare effects of climate policy						
Ability to analyze impacts of carbon						
Transparency						
Documentation						
Model available online						

Yes/Represented
Limited
None/Not represented

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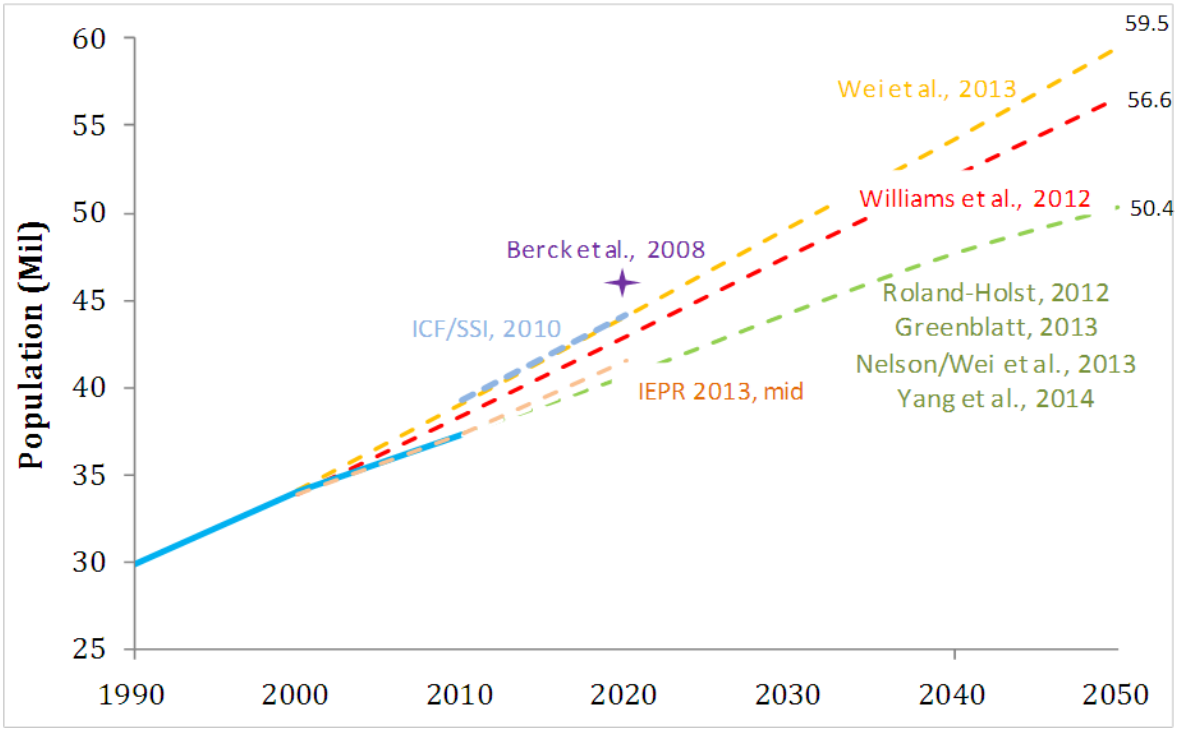
Population Assumptions



BEAR – DOF (2013)

CA 2050 - U.S. Census (2005)

CA-TIMES - DOF (2013)

E-DRAM - DOF (2003)

Energy 2020 - IEPR (2009)

GHGIS - DOF (2013)

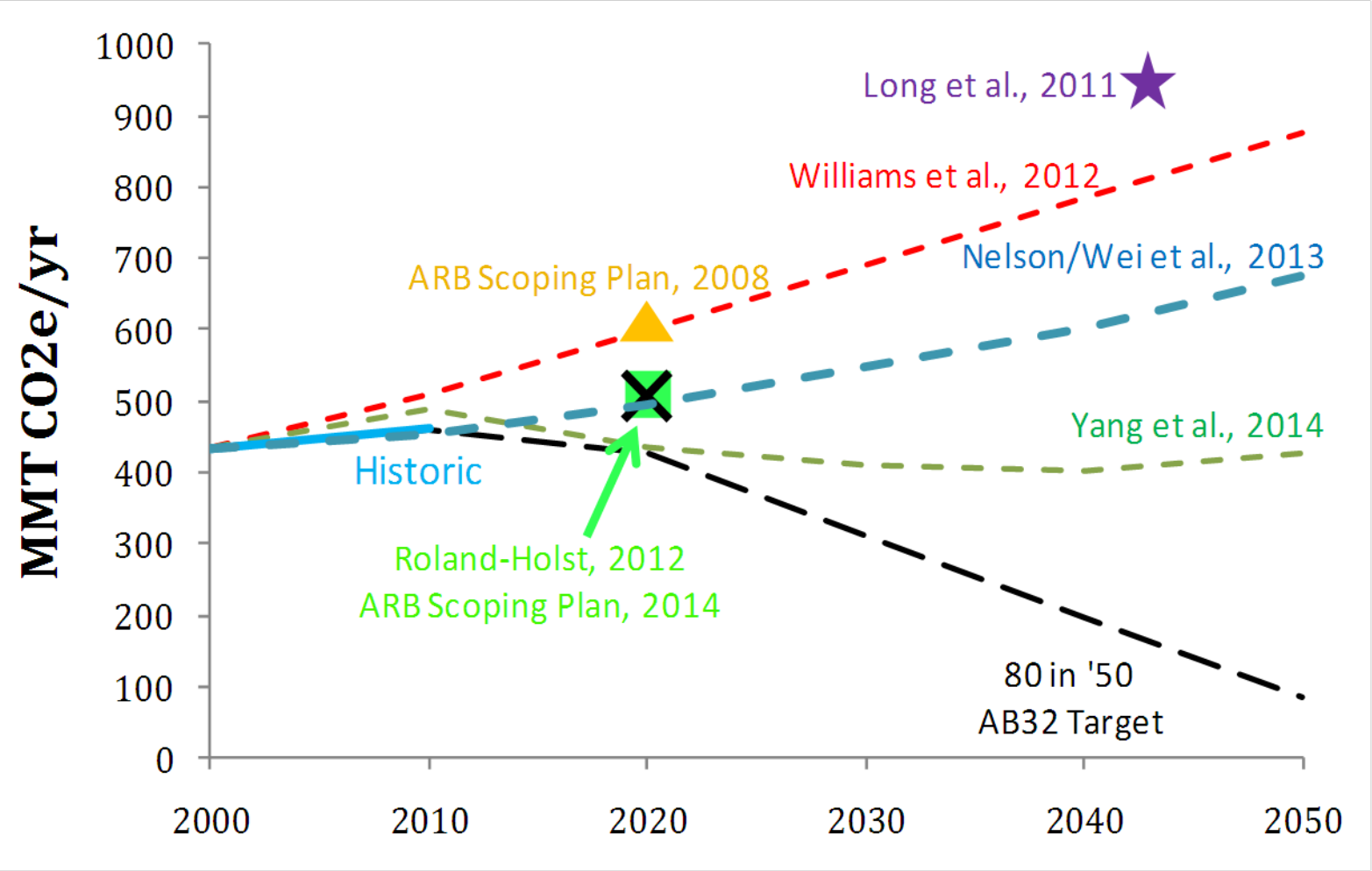
IEPR 2013 - IHS Global Insight for Mid projection

LEAP-SWITCH - AEO (2011)

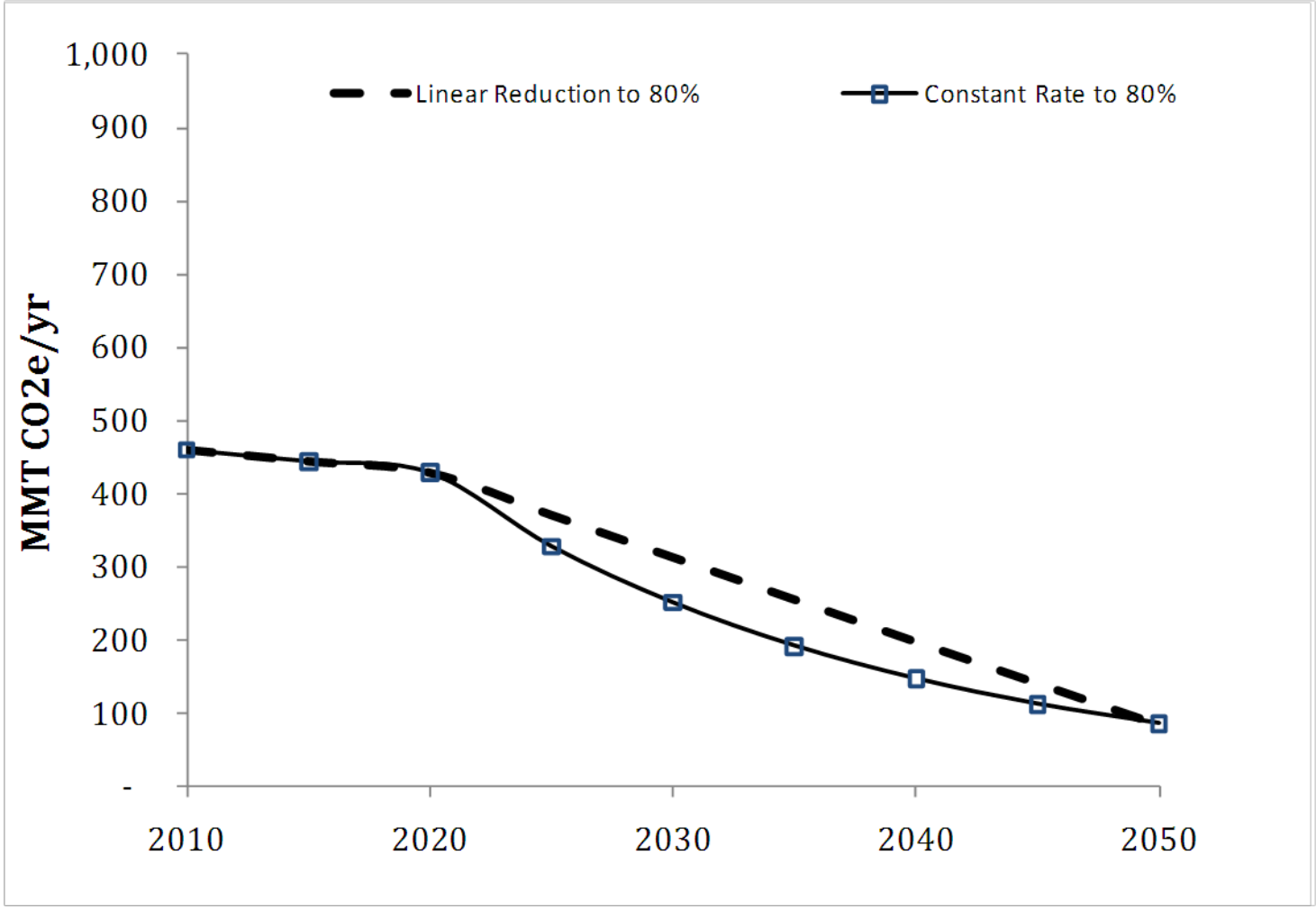
VISION - AEO (2011)

WWS - U.S. Census (2009)

Business As Usual (BAU) Scenarios



Reaching 80 in ‘50 Goals



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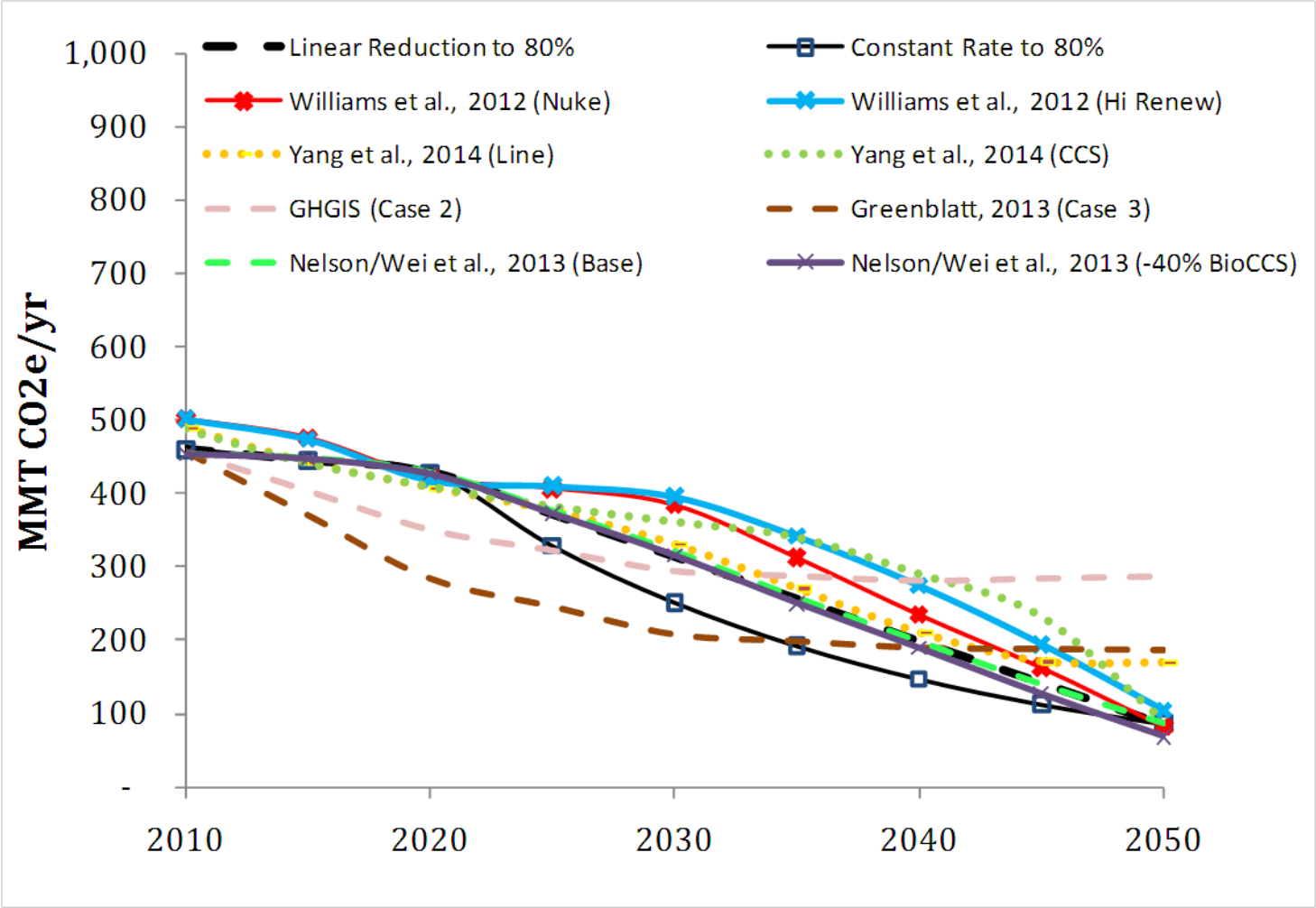
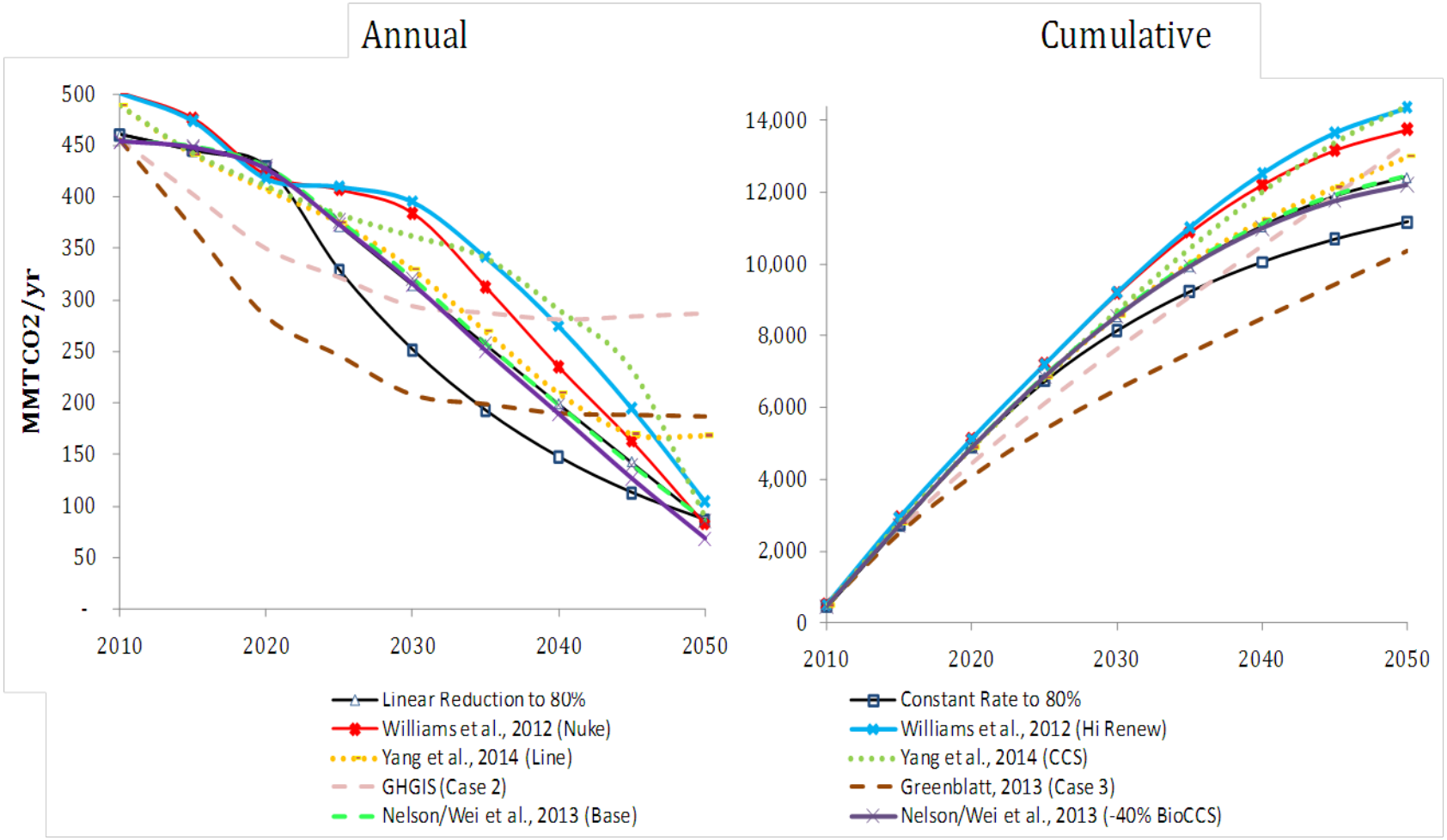


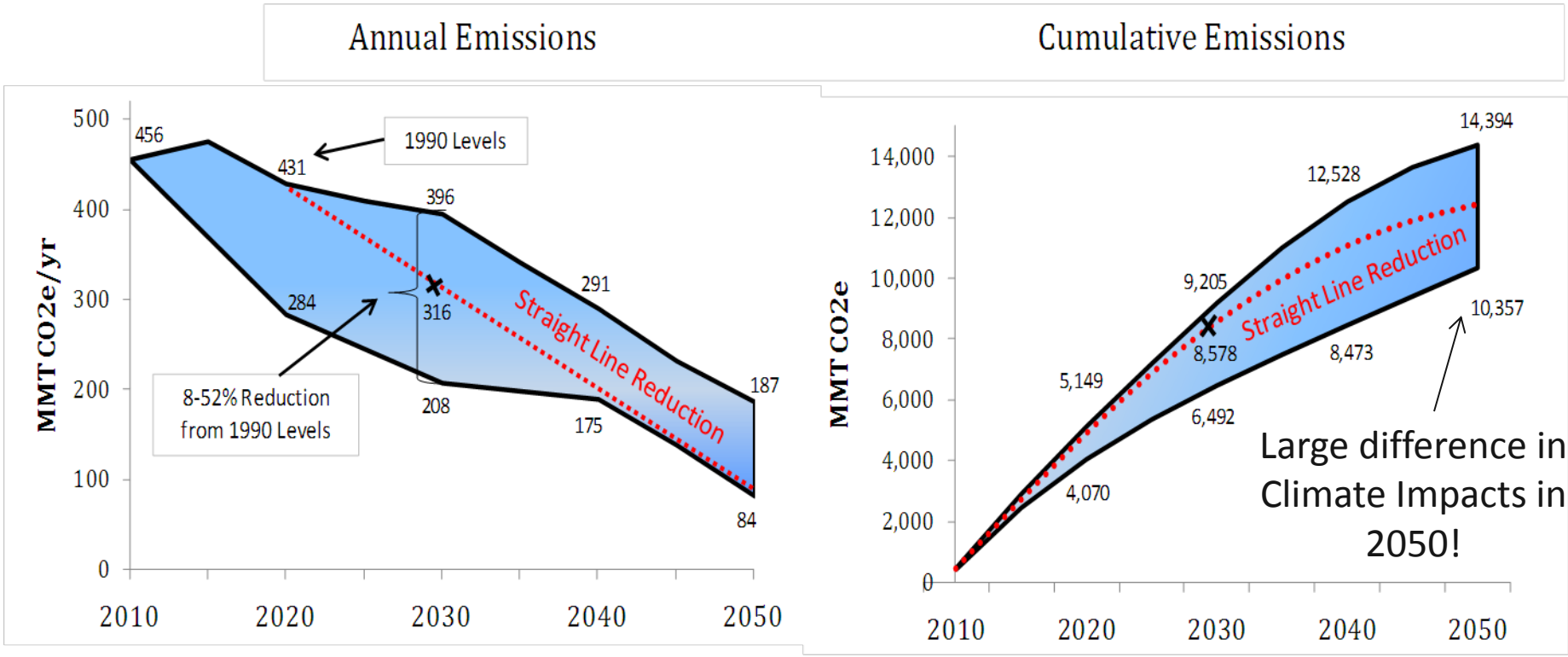
Annual vs. Cumulative Emissions?



Annual Emissions = Economy-wide emissions each year (e.g. all emissions in 2010)

Cumulative Emissions = The sum of annual emissions since the year 2010
(e.g. emissions in 2010 + emissions in 2011 +…. emissions in year X)

Annual vs. Cumulative Emissions?



Annual Emissions = Economy-wide emissions each year (e.g. all emissions in 2010)

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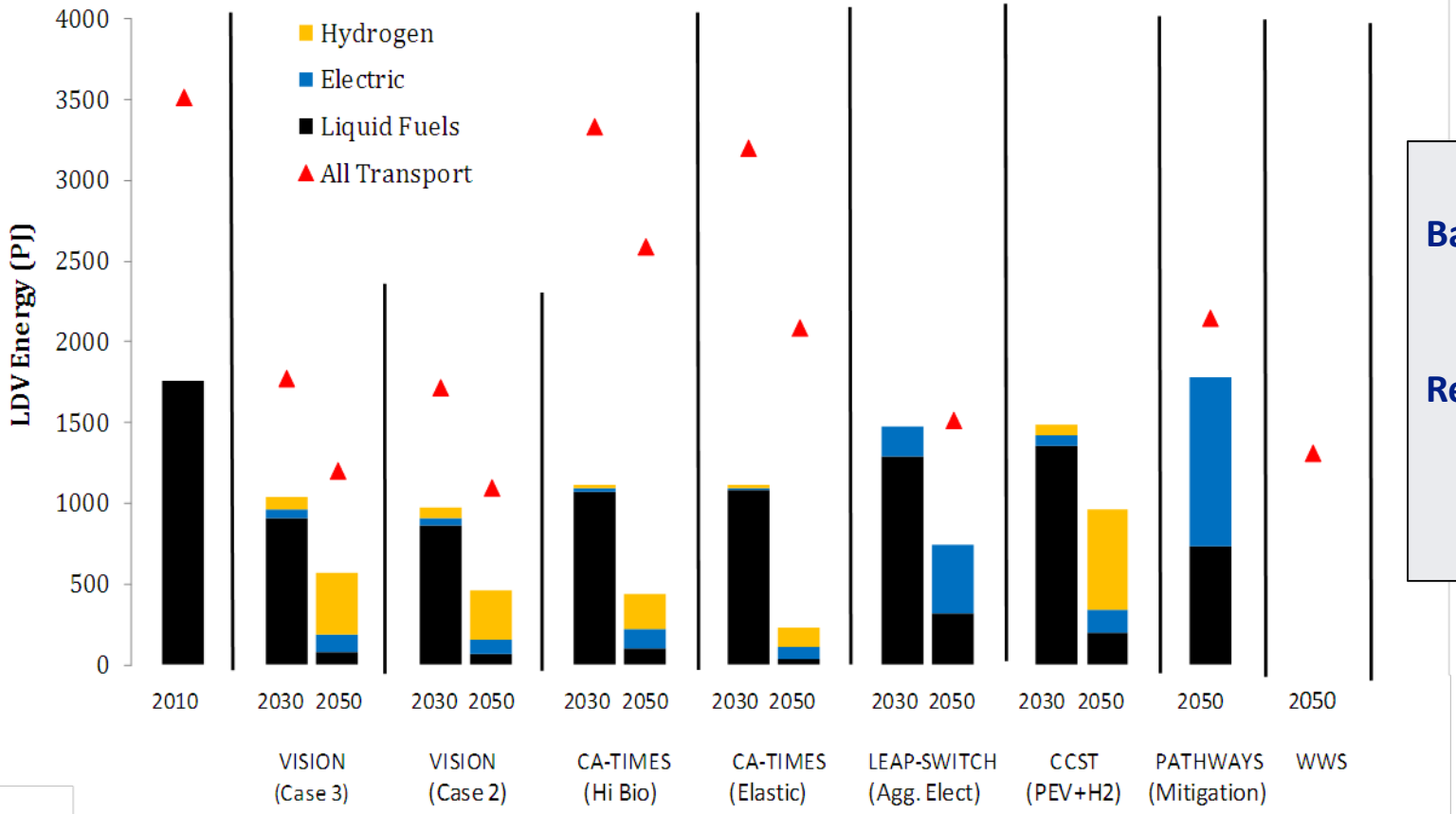
Light-Duty Vehicle Energy Use, 2030 & 2050



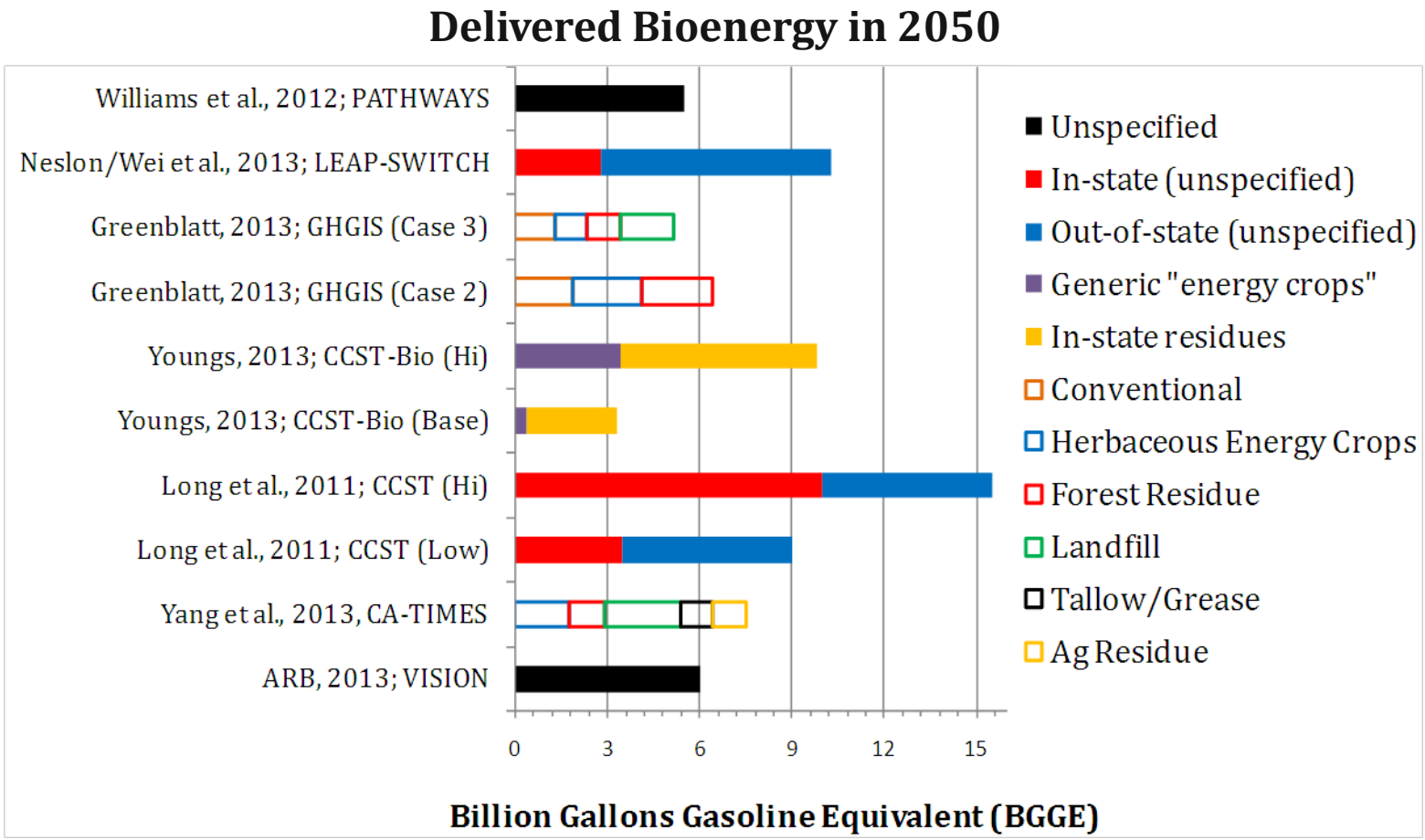
LEGEND

Bars = LDV energy use by source

Red triangles = total transport energy use

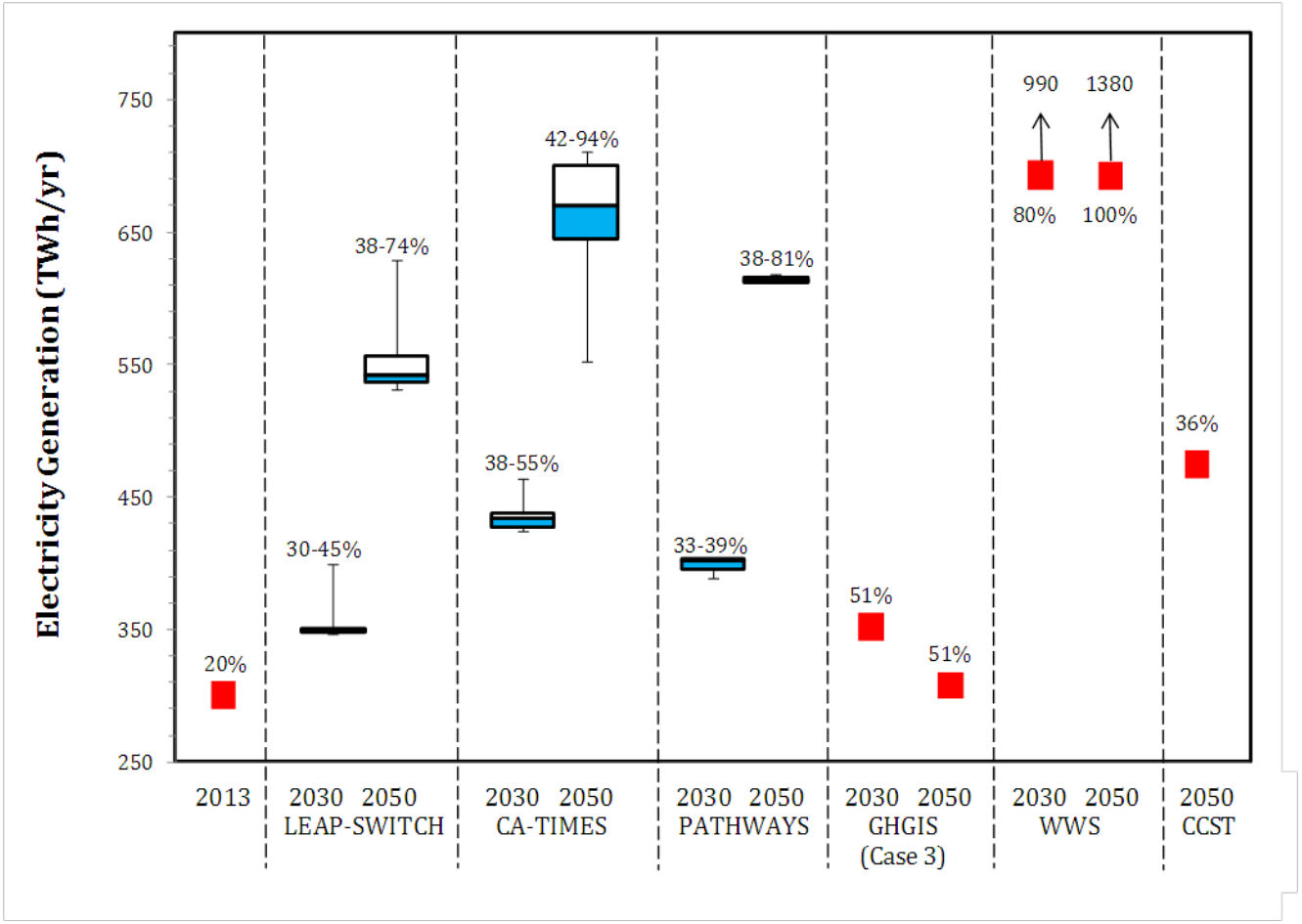
- In mitigation scenarios, electricity and hydrogen provide 3-13% of Light Duty Vehicle (LDV) delivered energy in 2030 and 57-87% by 2050
- Total transportation energy drops by as much as 70% from 2010-2050 due to increased vehicle efficiency and changes in Vehicle Miles Traveled (VMT).

Liquid Biofuels are Important but Assumptions Matter!



- ~1 BGGE in 2010
- "Advanced" bio-liquids could power up to ~40% of transportation sector in 2050
- Bio-energy goes to transportation, not to electricity
- Large carbon savings from bioenergy+CCS (more modeling needed!)

Electricity Generation and Renewable Fraction in 2030 & 2050



LEGEND

Box plot = quartiles (box) and max/mins (whiskers) across mitigation scenarios in given year

Red squares = individual scenarios

Percentages above boxes are percent renewable (non-hydro) across mitigation scenarios

- Renewable fraction (non-hydro) ranges from 30-51% in 2030 and 36-96% in 2050 (non-WWS)
- Total generation goes from 306 TWh in 2013 to 290-990 in 2030 and 245-1380 in 2050
- Implied renewable build rate is 0.2-4.2 Gigawatts per year (GW/yr) between today and 2030 and 1.5-10.4 GW/yr between 2030-2050

Criteria Emissions

	Tracked Pollutant Emissions						Pollutant Concentrations	
Model	NOx	ROG	PM2.5	CO	SOx	NH3	PM2.5	O3
ARB VISION								
CA-TIMES								
BEAR								
GHGIS								
PATHWAYS								
LEAP-SWITCH								

	Yes/Represented
	Limited
	None/Not represented

- Coordination needed between 2023 and 2032 ambient air quality goals and long-term climate goals (and between relevant agencies)
- Need for zero and near-zero goods movement in near/mid-term (BAU scenarios do not achieve long-term NAAQS in South Coast and San Joaquin Valley Air Basins)

Key Takeaways

- Different models provide different and useful perspectives and findings
- Achieving a deep reduction in emissions of 80% below 1990 levels appears technically plausible
- Based on those "deep reduction scenarios" (i.e. 80 in 50):
  - 208-396 MMT CO2e/yr in 2030
  - 8-52% reduction in GHG by 2030 from 1990/2020 levels
  - Cumulative emissions vary by as much as 40% in 2050
  - 30-50% renewable grid by 2030
  - 38-94% renewable grid by 2050
- Electrification of end uses (e.g. transport, heat) and expansion of grid are key
  - Need to expand grid by 1.5-2.5 times its current capacity even assuming significant efficiency gains

Key Takeaways (continued)

- Need greater understanding about how to use biomass for energy and fuel
  - More modeling of bio-energy+CCS
  - More modeling of life cycle emissions and other sustainability factors
- Need to address criteria emissions and other non-energy related GHG emissions (e.g. BAU scenarios have non-energy GHG emissions >2050 target)
- Need for better modeling of explicit policies and technologies (within California and beyond)
- **Data availability and data/model transparency is essential**
- Coordination across agencies (and with other jurisdictions) is key

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Please see our CCPM summary document and forthcoming white paper here:
http://policyinstitute.ucdavis.edu/initiatives/ccpm/

Thank you!

Extra slides (not for printing)

Emission targets in developed world

- US (Copenhagen Accord) – **33%** below 1990 levels by 2030
- Euro Union – **40%** below 1990 levels by 2030 (under negotiation)
- Denmark – **40%** below 1990 levels by 2030
- Netherlands, UK – **50%** between 2022-2027
- Germany – **55%** below 1990 by 2030
- Scotland – **42%** below 1990/5 levels by 2020 and **80%** by 2050
  - Expects to make **60%** reduction target in 2030

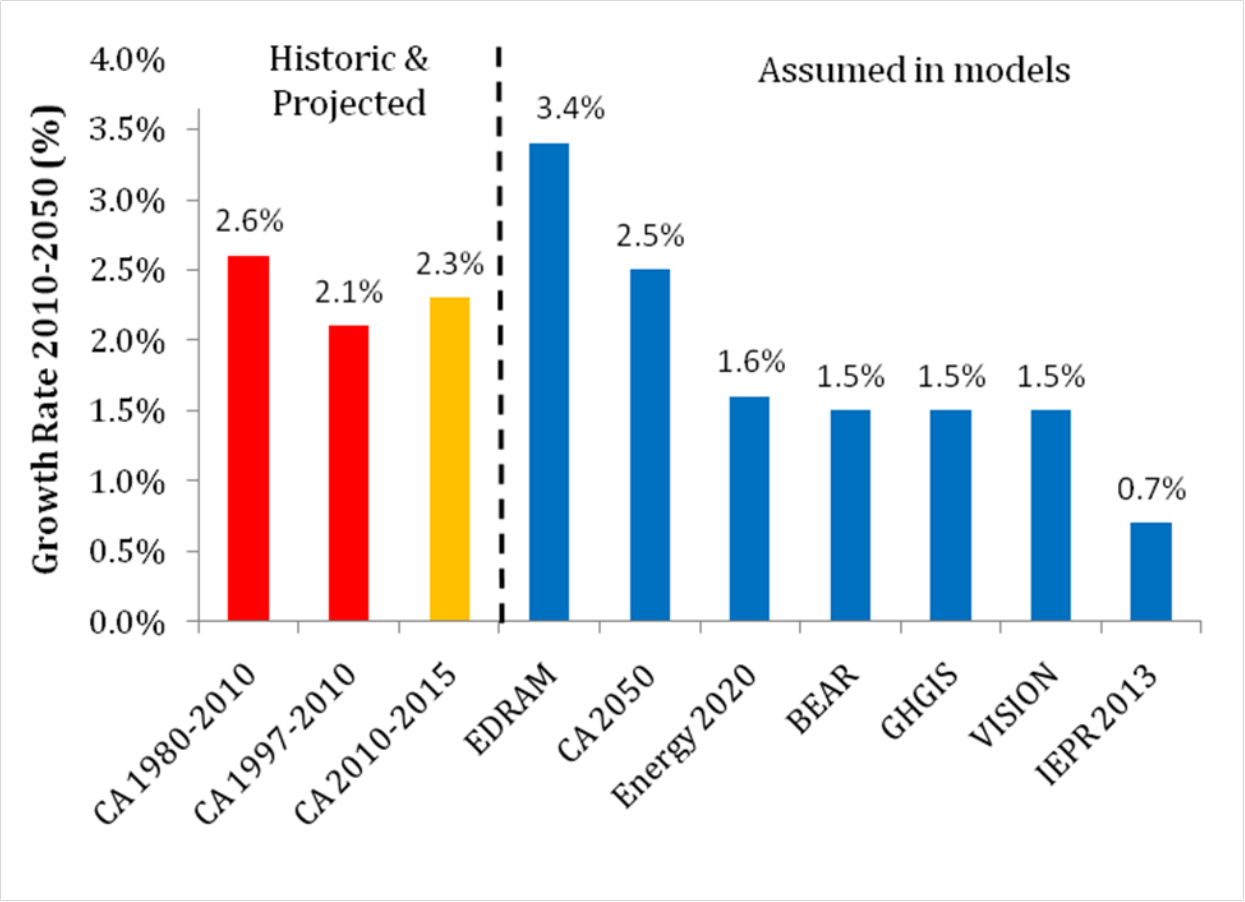
Coordination is Key in Meeting 2030 and 2050 Goals

- Between state agencies and with other state goals:
  - Air quality targets for San Joaquin and South Coast regions
  - Water use/quality
  - Health goals
- Between Western states:
  - WECC targets need to be aligned to avoid leakage, expand market for low-carbon technology, provide least cost mitigation measures
- Between modelers and policy makers

Observations from forum

- Models built to examine pathways to 2050 → not specifically focused on maximizing climate benefits by 2030 (except GHGIS)
- Many models limited in ability to consider economic feedback and benefits/costs of policy options
- Limited representation of uncertainty
- Criteria emissions only included in small number of models (and not part of the optimization process)
- Modelers need to work with policy makers more closely to represent the details of the policy design
- Data availability and data/model transparency is absolutely essential.

Income Assumptions



*Some models adjusted from nominal to real growth rates.
** Some models use personal income while other use GDP

CA 1980-2010 - Personal income (BEA, 2013)

CA 1997-2010 - GDP (BEA, 2013)

CA 2010-2015 – Personal income (DOF, 2013)

E-DRAM - Personal income (DOF, 2003)

CA 2050 - GDP (BEA, 2009) + Regressions

Energy 2020 - Personal income (IEPR, 2009)

BEAR – Per capita GDP **(AEO, 2011)**

GHGIS - Personal income (from VISION/IEPR, 2013)

VISION - Personal income (AEO, 2011)

IEPR 2013 - Personal income (IHS 2013; Moody's, 2011)

Why Do Inter-Model Comparisons?

- Sweeney, 1983
  - Model comparisons benefit the modeling community "through **identification of errors, clarification of disagreements**, and **guidance for model selection**"

- Weyant, 2012
  - **Understand Strength/weaknesses** of existing methodologies
  - **Identify high priority areas** for development of new data, analyses, and modeling methodologies

- Two levels of model comparisons:
  - Level 1: compare & contrast inputs & outputs (e.g. review article)
  - Level 2: standardize inputs, compare outputs (SRES, SSPs)